CPTEC
Centro de Previsão de Tempo e Estudos Climáticos

MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

# Plans and preparation for satellite sounders: Met Office, ECMWF, CPTEC and the NWP-SAF


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# Contents

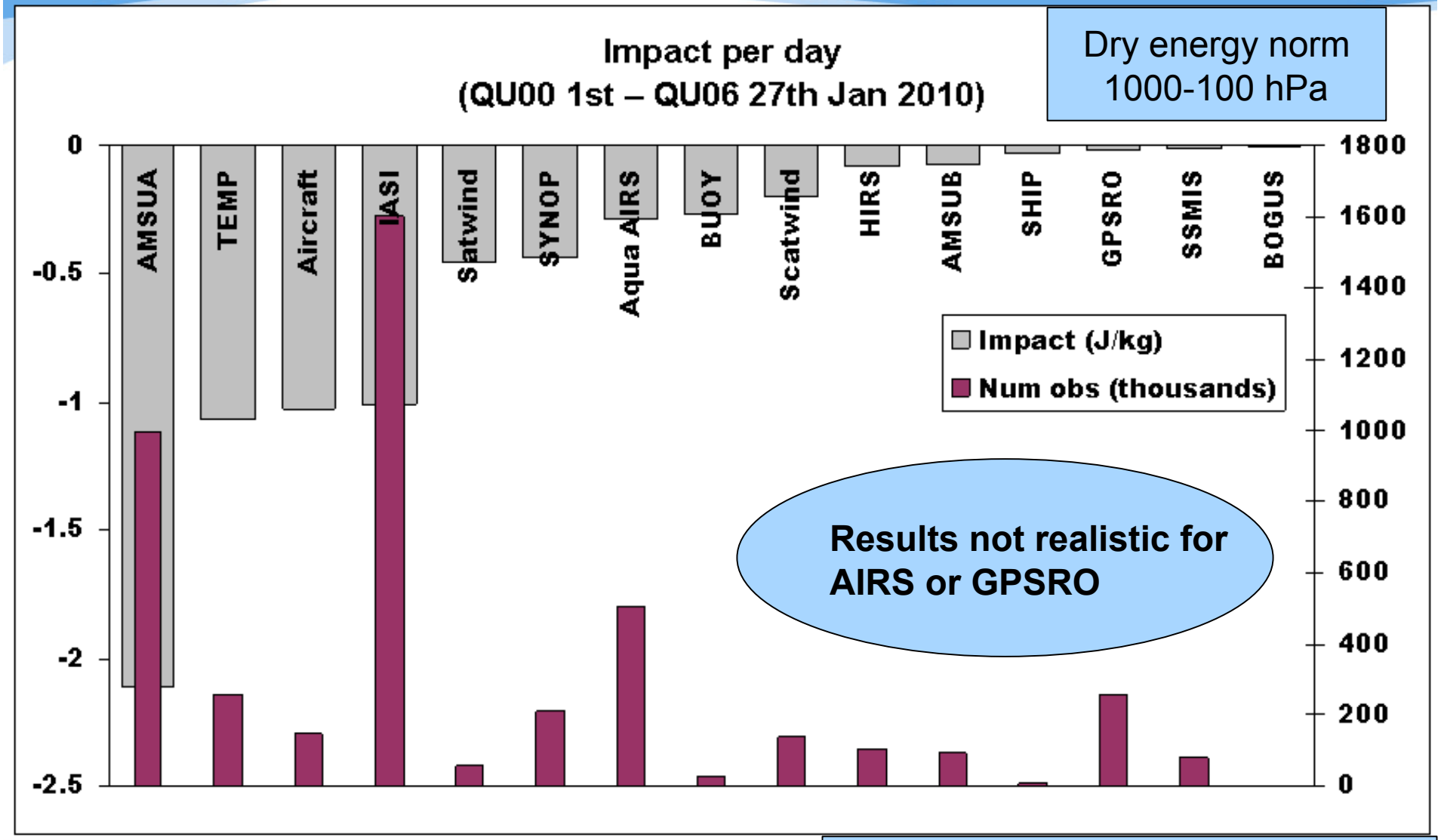
- Current use of NPP-like instruments in NWP (AIRS, IASI, AMSU, MHS, SSMIS)
- NWPSAF preparations for NPP
- NWP Centres strategy for NPP instruments (Met Office, ECMWF, CPTEC)

# NWP use of satellite sounders

# Satellite Data Assimilation

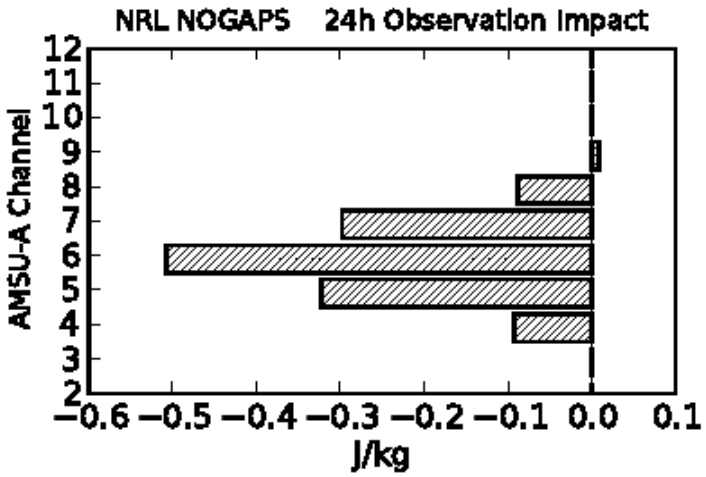
- Met Office, ECMWF: 4D-var
- CPTEC: PSAS, soon Local Ensemble Transform Kalman Filter
- Hybrid...4D-var+EKF
- ECMWF+Met Office:
  - Radiances: IASI, AIRS, ATOVS, SSMIS, SEVIRI
  - GPSRO bending angle
  - ASCAT and WindSat wind vectors
  - AMVs

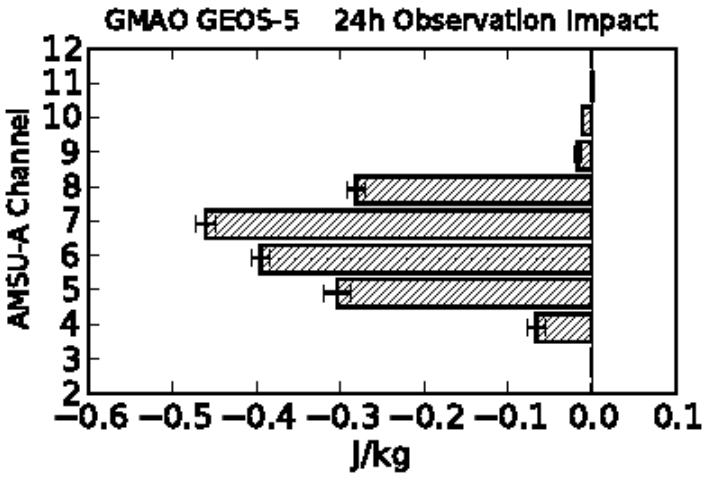
# Adjoint sensitivity: obs impact (Met Office)

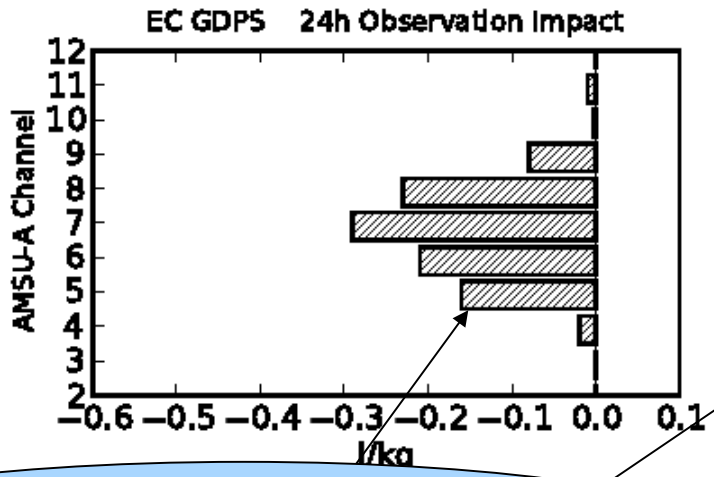


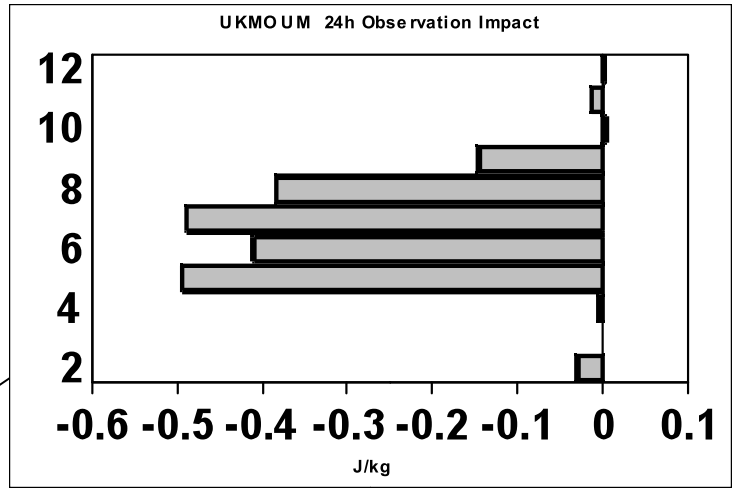

From Richard Marriot, Met Office

# Inter-comparison of AMSU-A channel impacts



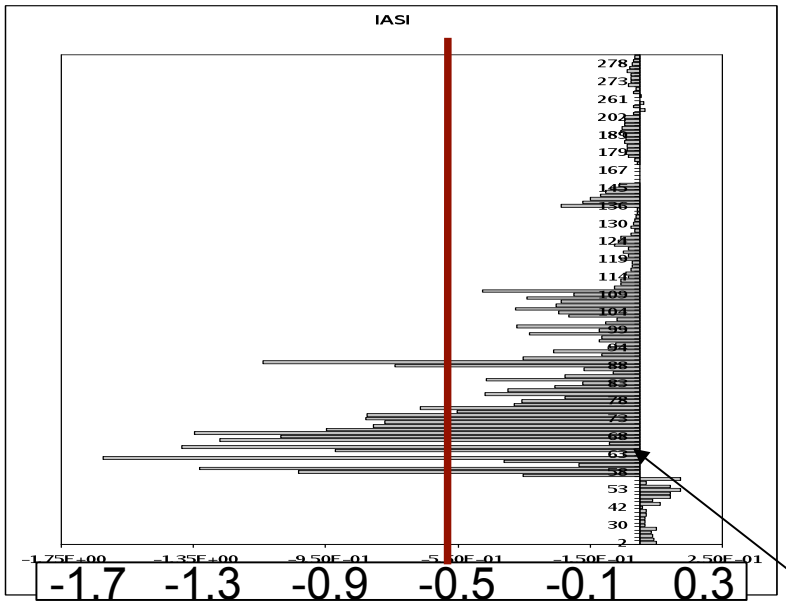



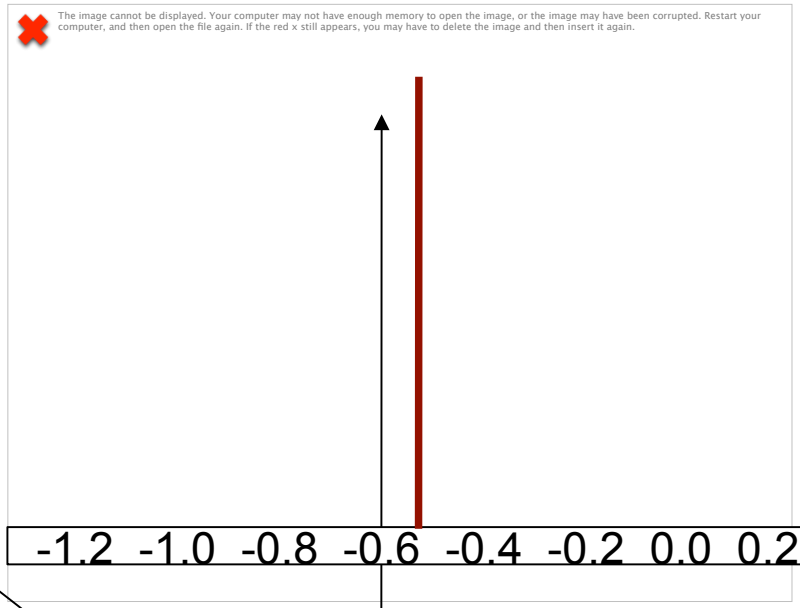



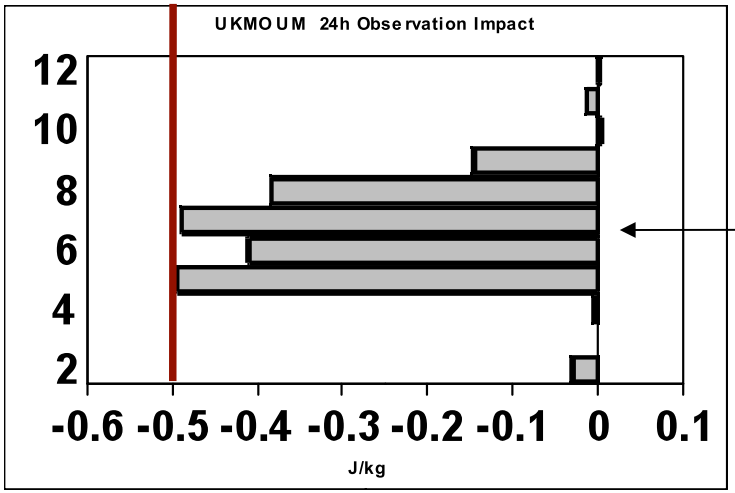

Note AMSU Ch.5 difference.
Met Office 4D-var analyses liquid water.

From Richard Marriot, Met Office

# Comparison of IR and MW channel impacts




Note best HIRS and IASI impacts larger than best MW channel.

From Richard Marriot, Met Office

# Current Met Office assimilation of AIRS + IASI

- **1D-Var pre-processor**
  - Quality control
  - Convergence test
  - Retrieve CTP, effective CF, skin temp.
  - Bias correct
  - Over land only use channels peaking above 400 hPa
- **4D-Var**
  - Assimilate BTs from 138 channels (IASI), 142 channels (AIRS). Only channels with Jacobians peaking above cloud.

From Ed Pavelin, Met Office

# How can we represent emissivity in 1D-Var?

- IR surface emissivity has large spectral variability
- Retrieving emissivity in *n* channels adds *n* unknowns to state vector
- Use **principal component analysis** to compress the emissivity spectrum

From Ed Pavelin, Met Office

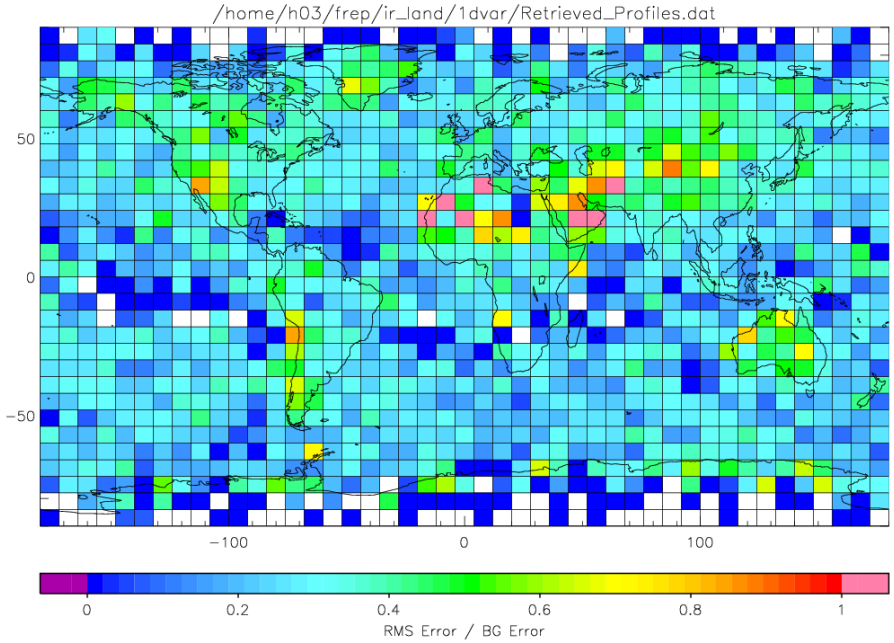
# Advantages of PC-based emissivity analysis

- PC-based approach
  - Use prior knowledge of spectral variation of emissivity (from lab measurements)
  - Constrains solution to realistic values
  - Retains realistic correlations between channels

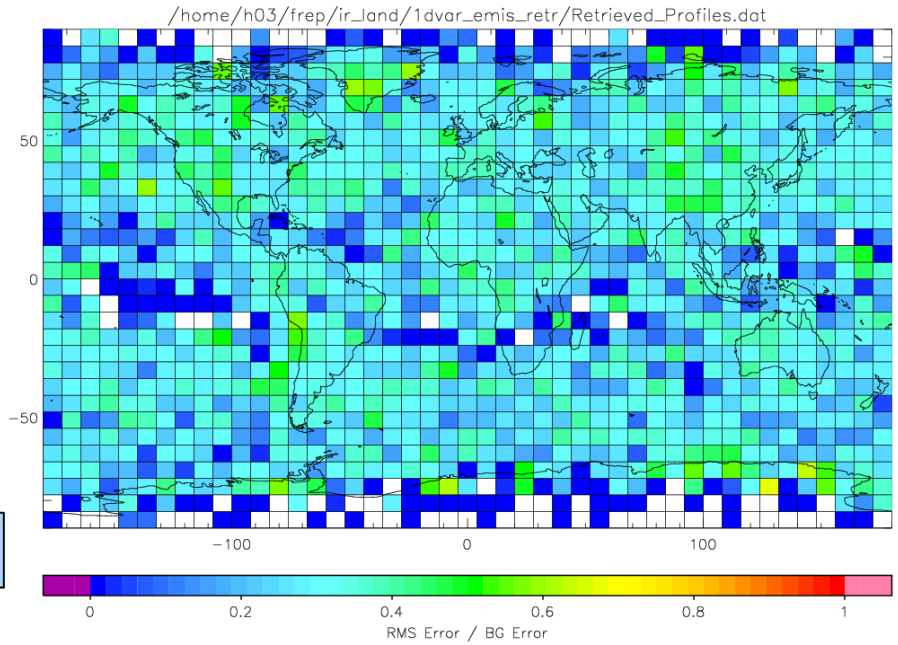
→ **Helps to separate $T_{skin}$ and $\varepsilon(\lambda)$**

From Ed Pavelin, Met Office

# 920 hPa T RMS analysis error (simulated)



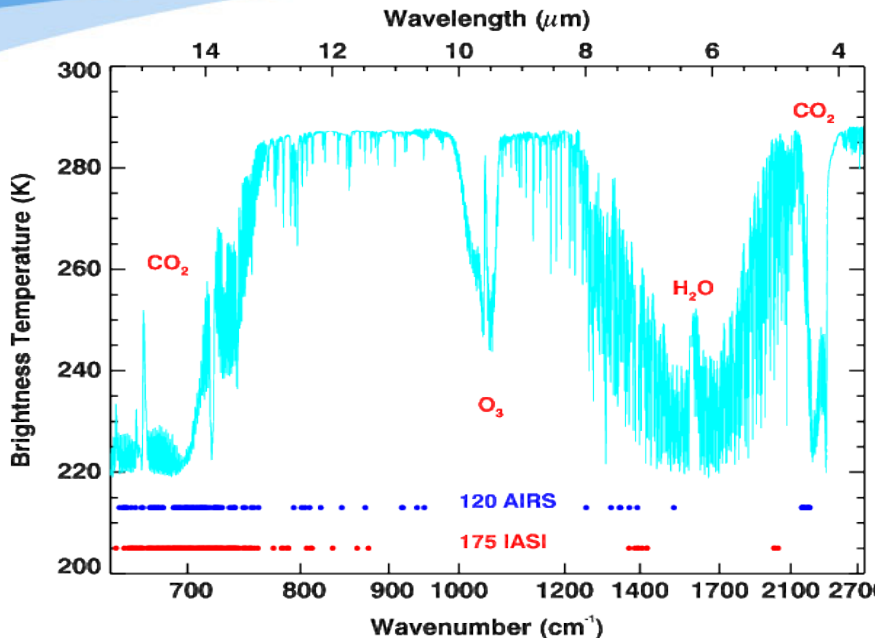

Without PC emissivity analysis

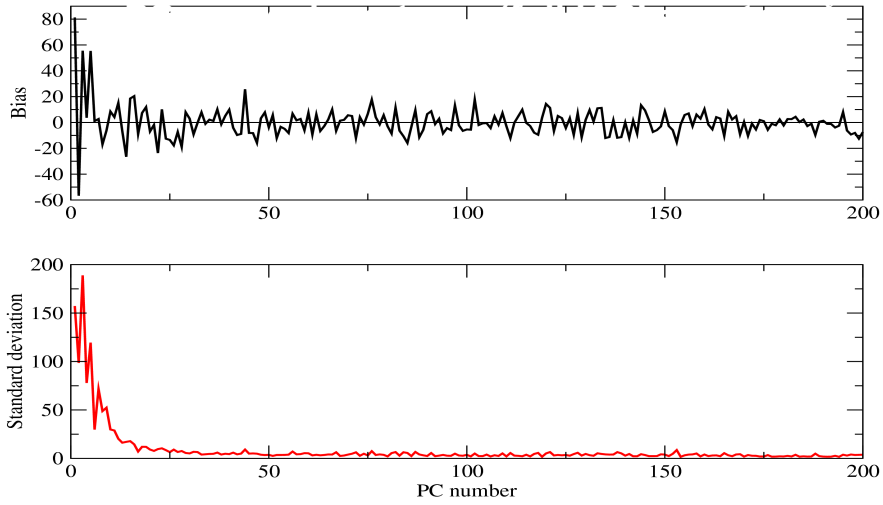



With PC emissivity analysis

From Ed Pavelin, Met Office

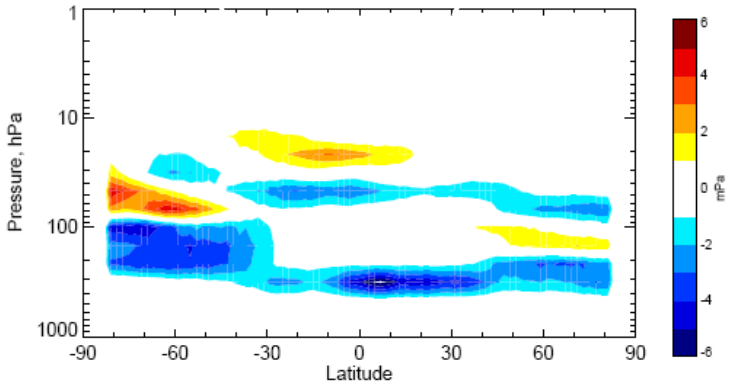
# Current use of AIRS/IASI data at ECMWF

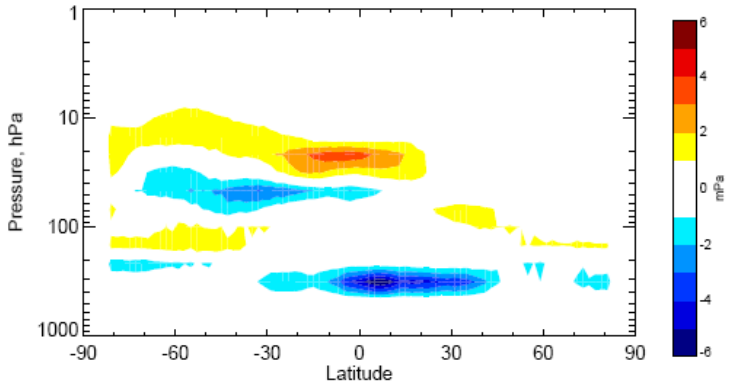



- October 2003: AIRS $CO_2$/$H_2O$ channels July 2007: IASI $CO_2$/$H_2O$ channels
- March 2009: In fully overcast situations, AIRS (not IASI) over land surfaces/sea-ice.
- Early 2011: Assimilation of 16 $O_3$ sensitive channels (together with UV TCO retrievals).
- Research towards use of shortwave AIRS channel assimilation at night.
- Research towards use of IASI shortwave PCs (noise reduction).
- Assimilation of $CH_4$ sensitive radiances in MACC (hosted by ECMWF).

# $O_3$ analysis verification with MLS



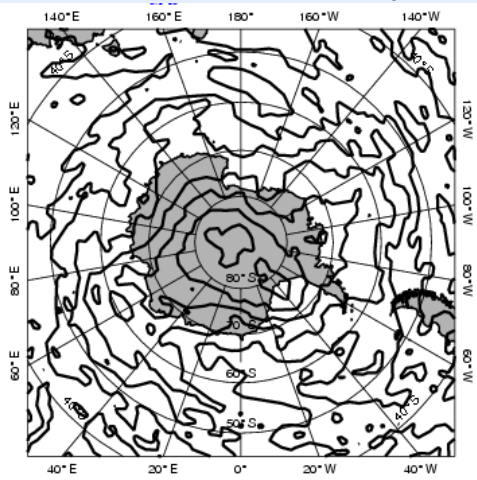




IASI improves mean fit to MLS compared to SBUV/OMI but produces overshooting at higher altitudes due to lack of sensitivity, i.e. both products are needed.

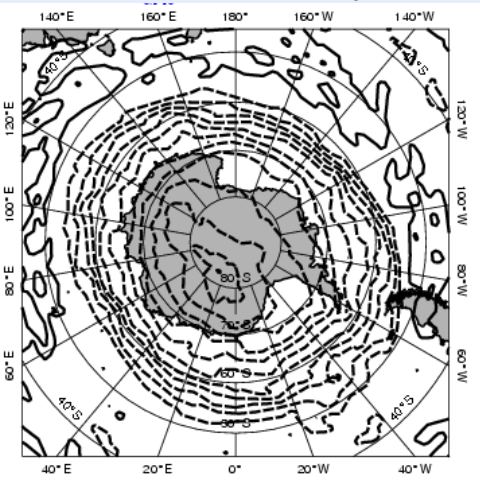
During the 2009 southern polar winter the analysis using IASI data successfully captured a ***change of sign*** from the mid-latitudes to the high latitudes (from ozone addition to ozone depletion).

The UV based system had no observational sampling of the higher latitudes (as there is no daylight) and extrapolated the addition of ozone from the lower latitudes.

**AN(SBUV+OMI) – NoO$_3$Obs**

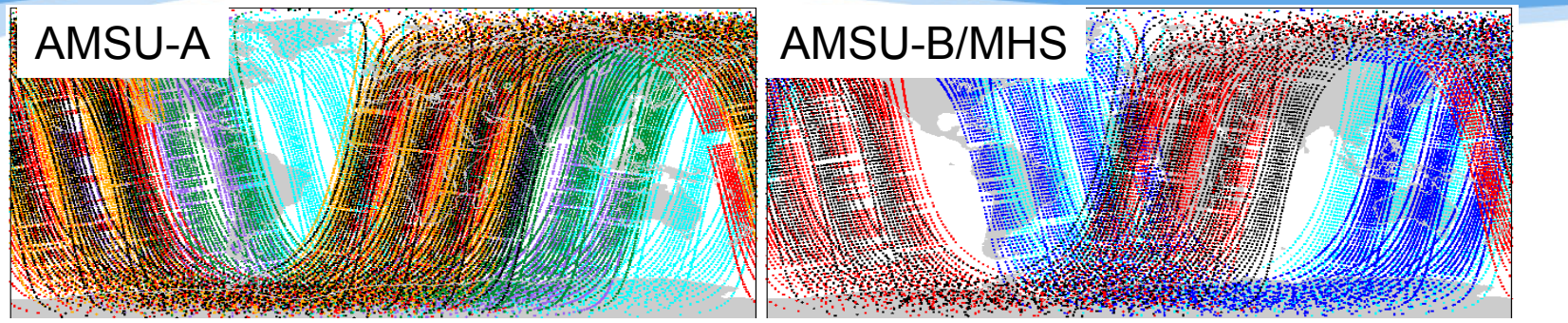


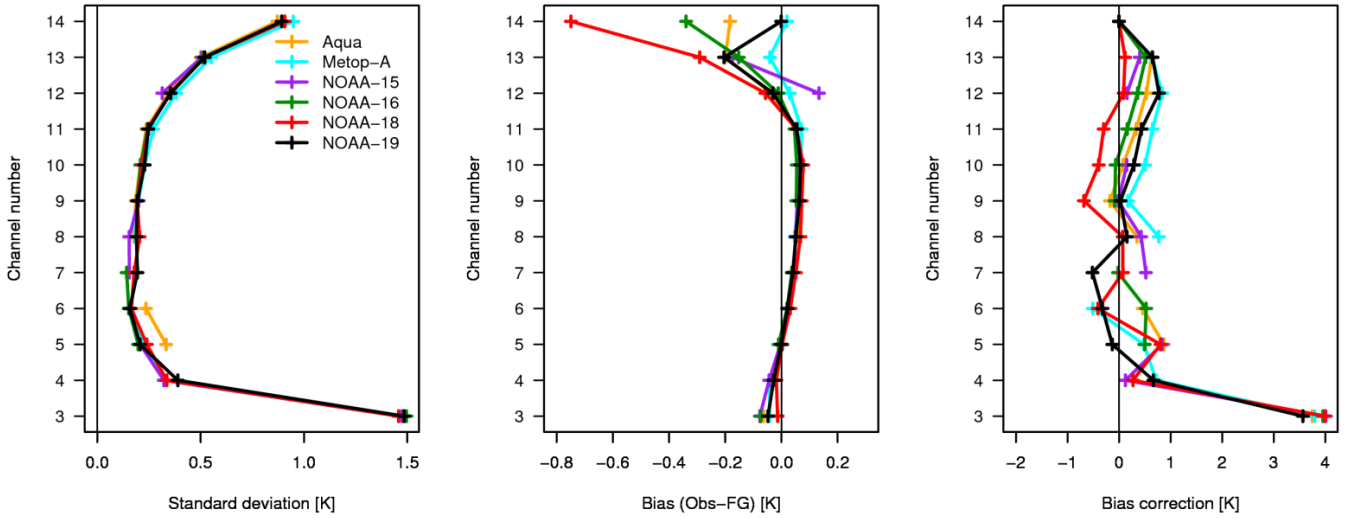

**AN(IASI) – NoO$_3$Obs**




From Tony McNally, Wei Han, Bauer, ECMWF

# 6-hourly microwave sounder coverage




- (Bias-corrected) model-minus-observation standard deviations define requirements for instrument calibration accuracy/noise.
- Experiments suggest that 5th AMSU-A (NOAA-19) still produces noticeable impact.

From Niels Borman, Peter Bauer, ECMWF

# NWPSAF preparations for NPP

# NWPSAF preparation for NPP ATMS and CrIS

- For NWP use, the following pre-processing activities may be required:
  - Footprint broadening or narrowing, to control noise and beam width
  - Re-mapping from one instrument to another (e.g. AMSU to HIRS, AVHRR to HIRS)
  - Spectral and spatial thinning (principal components or channel subset (e.g. IASI, AIRS)
- Different users have different requirements
  - e.g. global versus regional NWP
- For NOAA and MetOp platforms these options are provided by the ***ATOVS and AVHRR Pre-processing Package*** (AAPP)
- Validation – errors match expectations?

From Nigel Atkinson, Met Office

# AAPP package

- Developed and maintained by the EUMETSAT NWP Satellite Application Facility (NWP SAF)
- See www.nwpsaf.org
- During 2010/11, AAPP will be extended to accept NPP data
  - ATMS and CrIS initially, VIIRS later

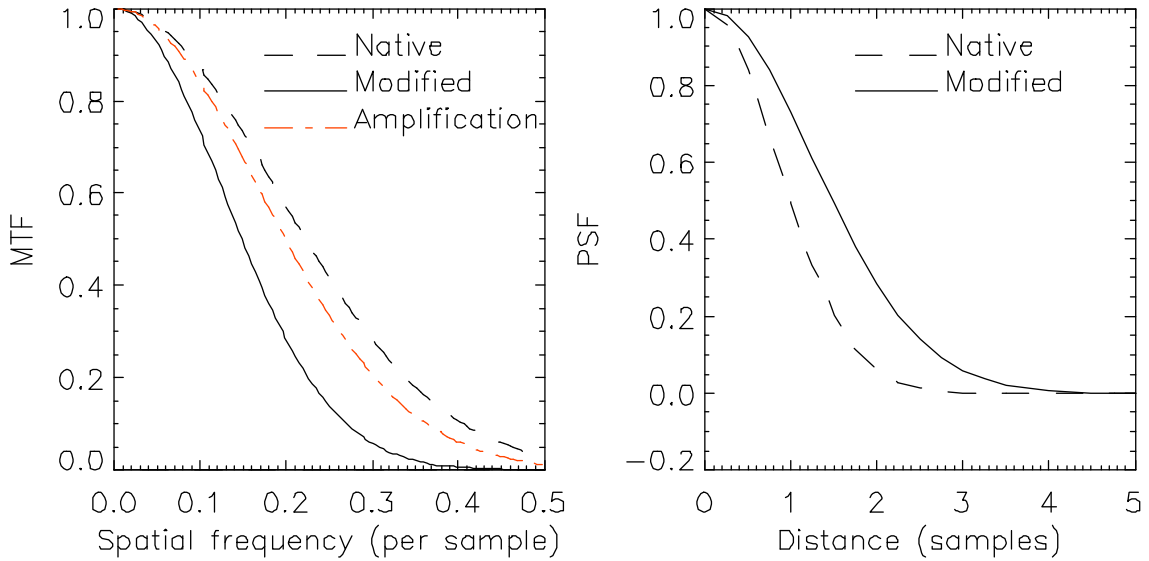
From Nigel Atkinson, Met Office

# ATMS footprint manipulation

- Footprint sizes vary: 5.2º, 2.2º, 1.1º
- Sampling distance is 1.1º for all channels
- As a consequence:
  - Temp sounding channels are ~3 times noisier than for AMSU (in Temp Data Records)
  - 23.8 and 31.4 GHz channels are not matched to 50-55GHz
- These issues can be addressed in the pre-processing

From Nigel Atkinson, Met Office

# Broadening the beam width: - temp sounding channels

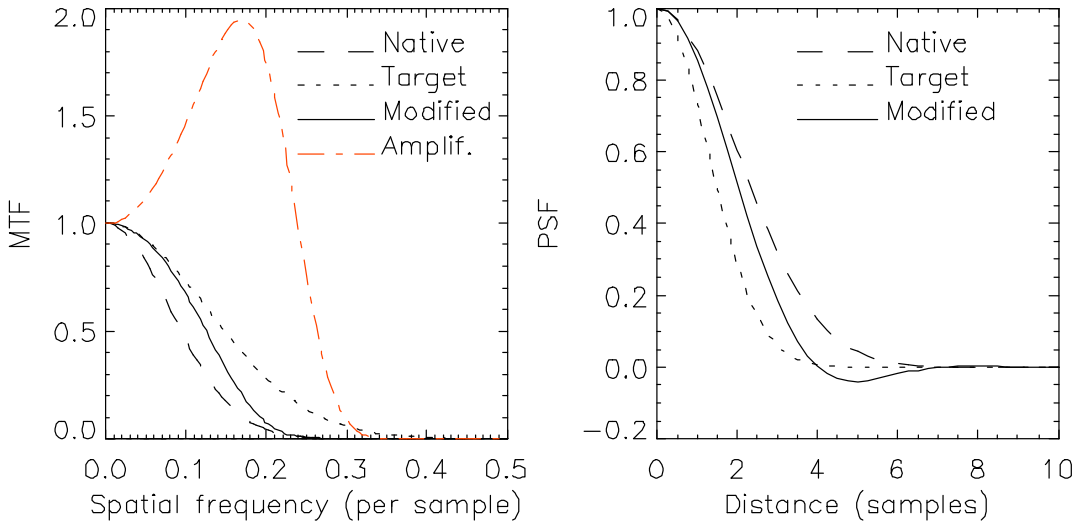



2.2° to 3.3°

- Relatively easily done using FT technique or Bachus Gilbert
- Sample averaging (3 x 3) is an alternative
- Noise reduction factor is ~0.3

From Nigel Atkinson, Met Office

# Narrowing the beam width: 23.8 and 31.4 GHz




5.2° to 3.3°

- Cannot be done perfectly, but can do a reasonable job at the lowest spatial frequencies
- Noise factor is ~0.7 in the example above

From Nigel Atkinson, Met Office

# Data volume issues

- CrIS full-spectrum data volume will be ~350Mb per hour (from simulated NOAA data, BUFR encoded)
  - c.f. IASI 700Mb per hour
- Too large for cost-effective near-real-time dissemination (e.g. EUMETCast for European users). Options are
  - Channel subset (as for AIRS and IASI)
  - Principal components (but not accommodated in current NOAA BUFR sequence)
  - Spatial subset – e.g. choose spot least likely to be cloud affected (option for end user, but prefer to disseminate all spots)
- Similar issues for the forthcoming EARS-IASI service (366 channels, 290 PCs, full spatial resolution).

From Nigel Atkinson, Met Office

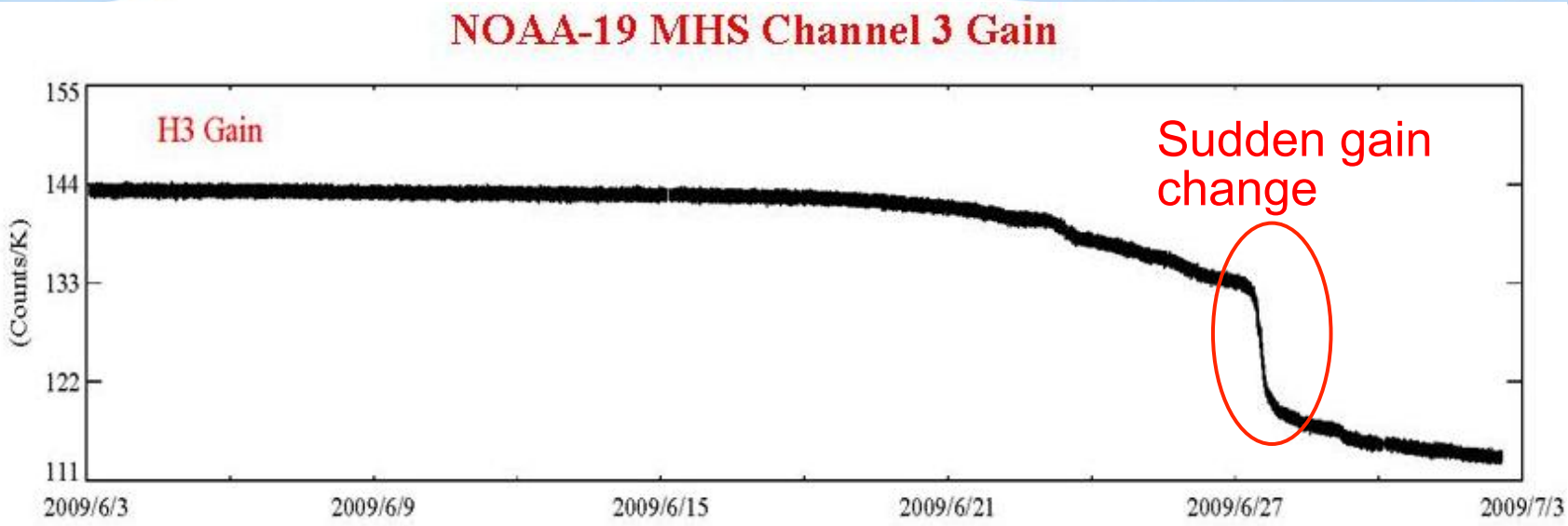
# NWP support to cal/val for recent missions

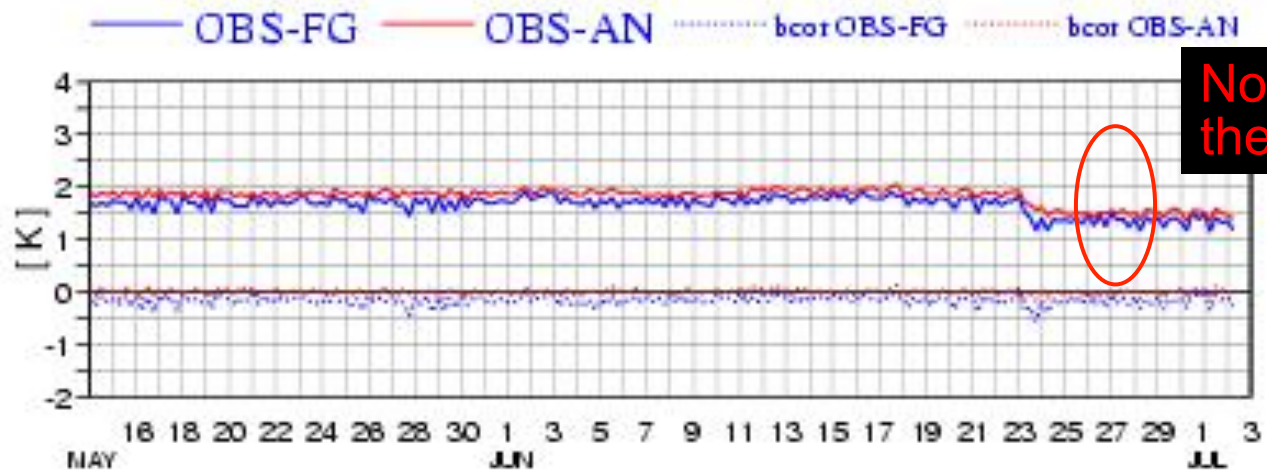
- NOAA-18 & 19 (ATOVS)
- DMSP F16, F17, F18 (SSMIS)
- MetOp-A (IASI, ATOVS, ASCAT, GRAS)
- FY-3A Microwave Temperature Sounder (MWTS)

Several NWP centres monitor observed minus model-predicted radiances – see linked web pages from www.nwpsaf.org

From Bill Bell ECMWF and Nigel Atkinson, Met Office

# Recent example – NOAA-19 MHS

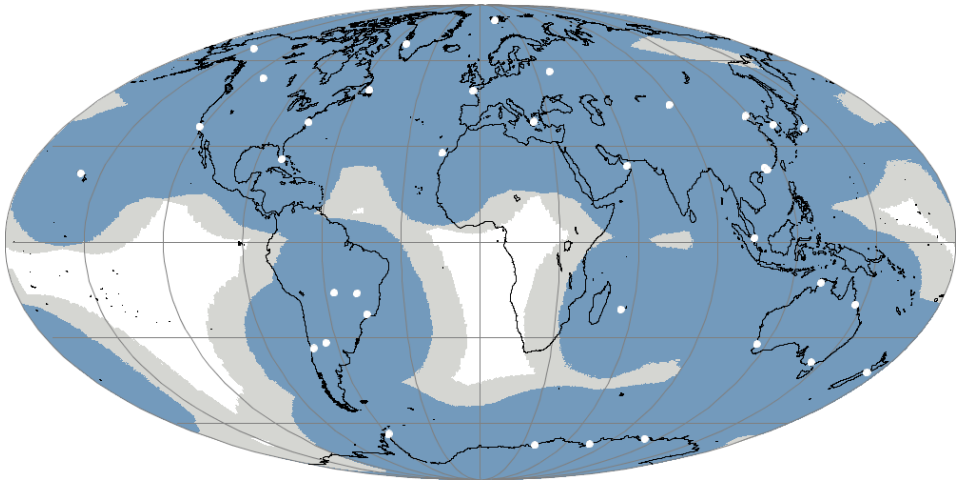



From Nigel Atkinson, Met Office

# By the end of the NPP cal/val period …

- Capabilities established to assimilate ATMS/ CrIS data into NWP
- IPOPP and AAPP working together for locally received Direct Readout data
- Start setting up RARS network for JPSS. RARS is a WMO initiative to provide timely (30 minutes) regional sounder data



*RARS network 2010*

From Nigel Atkinson, Met Office

# Conclusions

- Use of hyperspectral sounders is becoming more sophisticated at NWP centres.
  - Data is increasingly used in presence of clouds, over land surfaces/sea-ice.
  - Entire spectral range is increasingly used (trace gases, PCs).
  - NWP-systems provide excellent tools to test instrument impact/monitor instrument performance (necessary input for all cal/val activities).
- Microwave observations remain important.
- Plans are well advanced for use of NPP sounder data in NWP centres and in the NWPSAF.
- NWP centres wish to continue to support cal/val for all future sounders, notably NPP.

# Extra slides

- More details on NWPSAF progress

# NWPSAF – tasks already completed

- Using the BUFR test data for ATMS and CrIS, from NOAA ftp://ftp2.orbit.nesdis.noaa.gov/smcd/czhang/
- AAPP to work with the BUFR data and generate level 1d products (binary and BUFR) with ATMS mapped to CrIS.
- ATMS averaging is done first using either FFT techniques or simple averaging (e.g. 3x3).
- The user can specify the required beam width, but an AMSU-A-like beam width (3.3 deg) is recommended for the sounding channels, which reduces noise by a factor ~3.
- The re-mapping to CrIS uses the actual geolocations rather than nominal scanning geometry; this minimises the need to equip AAPP with built-in assumptions about the scan geometry.

From Nigel Atkinson, Met Office

# NWPSAF – in progress (Nigel Atkinson)

- Add AAPP microwave cloud and scattering indexes for rain detection.
- AAPP has provision for generation of CrIS principal component scores and inclusion in the 1d output.
  - At present we understand that there is no plan for NOAA to disseminate CrIS data in PC form, despite the potential for large data compression, and reduced noise in the reconstructed radiances.
  - EUMETSAT may do so, but this is not yet clear. Lost opportunity? EUMETSAT plan to disseminate ATMS/CrIS data via EUMETCast. Note recently started trial of IASI data dissemination in PC format.
- Add options to thin to 1 in 9 (e.g. warmest FOV) or 4 in 9.
- Add capability to run from SDR files in hdf5 format from IPOPP. IPOPP alpha release has been installed at the Met Office and is being tested with MODIS data.
- Would like to know when IPOPP beta release will follow, allowing testing for NPP instruments.

From Nigel Atkinson, Met Office

# Cal/val activities for NPP

*Evaluate SDR / TDR radiances only – not EDR*

- Compare O-B for ECMWF, Met Office and CPTEC, for ATMS and CrIS
- Are they consistent with expected? (bias and random)
- Are biases obtained from Simultaneous Nadir Overpass (SNO) representative of global biases?
- Look for spatial or temporal systematic biases
- If biases are found, correlate them with housekeeping data (e.g. instrument temperatures)
- Contribute to development of correction algorithms
- Model analysis fields could be made available to interested parties

From Nigel Atkinson, Met Office

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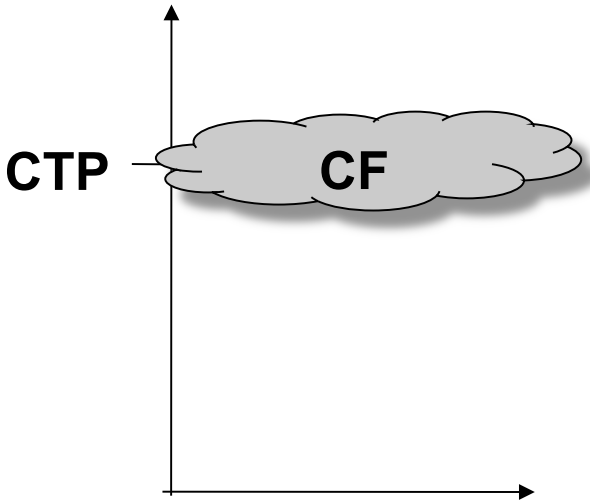
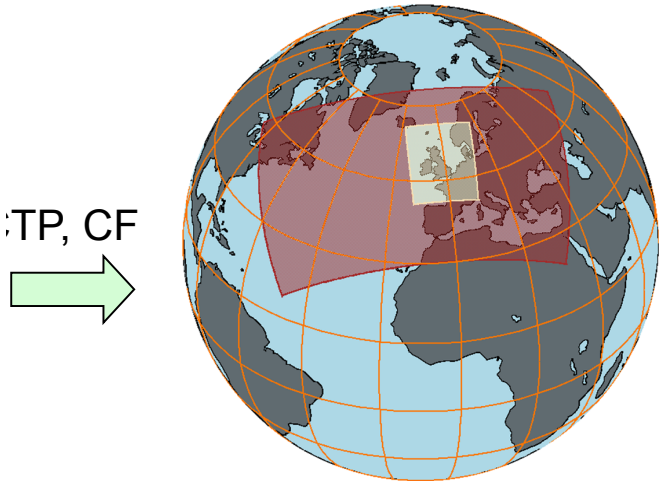
From Nigel Atkinson, Met Office

# 1D-Var cloud analysis




4D-Var

- Retrieve cloud parameters in 1D-Var
- Using RTTOV: Single level “grey” cloud

- Choose channels with minimal sensitivity below cloud top

- Pass cloudy radiances, retrieved CTP and CF to 4D-Var

From Ed Pavelin, Met Office

# Relative forecast error reduction per system

**IR+MW sounders represent most important observing system**

- IR + MW sounders are complementary (combined impact is larger than sum of individual impact).
- Current system of 2 advanced IR-sounders and 5+3 (AMSU-A + MHS) MW-sounders nearly optimal for NWP; however, atmospheric chemistry/air quality add special requirements (spectral coverage, spectral resolution, noise)*.

From Carla Cardinali, Peter Bauer, ECMWF

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